THE EFFECT OF LUNAR CRUSTAL THICKNESS ON THE MORPHOLOGIC TRANSITION FROM CENTRAL PEAK TO PEAK-RING CRATERS. *K.K. Williams and R. Greeley*, Department of Geology, Arizona State University, Tempe, AZ 85287-1404; email: kkw@asu.edu.

Introduction

Images of the Moon's surface reveal a variety of crater morphologies that can be related to crater size [1]. With increasing diameter, crater morphology progresses from simple to complex, central peak, peak-ring, basin, and finally multiring basin morphologies [1-4]. The transition from one morphology to another occurs when the shape of the crater becomes gravitationally unstable and collapses to a more stable form [5]. The simple to complex transition occurs over a diameter range of ~5 km [6], and it has been noted that the slight overlap in morphologies does not strictly follow a dependence on gravity [7]. Instead, there is a transition zone over which the evolution from one morphology to another takes place.

The transition from central peak crater to peak-ring crater is an example of a large transition zone, spanning a diameter range of some 100 km [1,4]. Craters in this transition zone have either a central peak, a peak-ring, or both a central peak and peak-ring. The transition zone is bounded by Tsiolkovsky and Antoniadi -- a central peak and peak-ring crater, respectively. These two craters are among ten used here to study the correlation between crustal thickness and crater morphology, providing insight into aspects of the crater formation process that are not fully understood [1,3,5].

Data and Analysis

The Clementine spacecraft [8] made near-global geophysical measurements during the two months it was orbiting the Moon. *Neumann et al*. [9] used the Goddard Lunar Topography Model-2 [10] to remove the topography component of the gravity from the free-air gravity model (Goddard Lunar Gravity Model-2 [11]). The resulting Bouguer gravity model was then used to derive a global crustal thickness map assuming that the lunar crust has a uniform density and that variations in the Bouguer gravity field are due to topography at the lunar crust-mantle boundary [9]. The lunar crustal thickness map exhibits a global variation of ~100 km over the Moon [9] but enables the calculation of average crustal thickness on a regional scale for any area on the Moon.

Lunar morphologic transitions were studied previously by relating crater dimensions (depth, diameter, terrace width, etc). While size relations give information about the physics of the impact process, consideration of other influences on crater morphology have been limited by available data. Influences such as crustal thickness can now be studied using Clementine data. Figure 1 shows average regional crustal thicknesses measured from the lunar crustal thickness map [9] plotted versus crater diameter for 3 central peak craters, 5 peak-ring craters, and 2 craters that have both a central peak and a peak-ring. Studies of crater formation processes suggest that the depth of the transient crater is approximately 35% of the crater diameter [3]. Following that relation, the dashed line in figure 1 shows that all of the peak-ring craters measured had transient cavities that extended deeper than the lunar crust-mantle boundary while the central peak craters did not. It is also noted that transitional craters with both a central peak and a peak-ring [2,4] plot along the dotted line, showing that their transient cavities extended to depths equivalent to the crust-mantle boundary. This suggests that the change in material properties at the crust-mantle boundary has a fundamental influence on the formation of peak-ring craters.

Discussion and Conclusions

The morphologic transition from central peak crater to peak-ring crater is not well understood. Crater formation models in which the morphology depends entirely on the crater diameter do not explain the large diameter range over which the morphologic transition takes place. For example, Antoniadi (188°E, 70°S) is a 135 km diameter crater with a well-developed peak-ring structure, but Tsiolkovsky (129°E, 21°N) is 33% larger than Antoniadi and has a central peak with no evidence of peak-ring formation [2]. Both craters fall in the transition zone between morphologies and were probably influenced by properties other than crater diameter, such as crustal thickness.

The global crustal thickness map [9] shows that Antoniadi and Tsiolkovsky formed in areas of very different crustal thickness. Antoniadi formed within the giant South Pole-Aitken basin in an area with a regional average crustal thickness of only ~34 km. Tsiolkovsky, however, formed in the lunar highlands in an area with a regional average crustal thickness of ~75 km. Using the dotted line in figure 1 as the depth of the transient cavity, it can be seen that Antoniadi, along with the other peak-ring craters, extended to depths greater than the crust-mantle boundary. Compton and Petavius extended to depths approximately equal to the boundary, retaining a central peak but also forming a low peak-ring. Central peak craters however, did not extend to the depth of the boundary. Figure 1 suggests that craters whose transient cavities extend through the crust will develop peak-rings, whereas other craters will have central peaks. We note that the paucity of peak-ring craters with diameters less than 250 km is likely due to the limited area of the Moon with a thin enough crust to allow smaller-diameter craters to extend at least to the crust-mantle boundary.

Using Tsiolkovsky and Antoniadi, the largest central peak and smallest peak-ring crater, respectively as examples, it has been found that the crustal thickness difference of approximately 40 km between the locations of the two impacts had a definite effect on the morphologies of the resulting craters. The thick crust beneath Tsiolkovsky allowed the crater to have only a central peak while having a diameter large enough that it might otherwise be expected to be a peak-ring crater. Antoniadi, however, has a small enough diameter that it should just be a complex crater, but the extension of its transient cavity into the lunar mantle caused it to develop a peak-ring. As craters that bound the transition from central peak to peak-ring craters, Antoniadi and Tsiolkovsky exemplify the dependence of morphology on crustal thickness. The transition from central peak to peak-ring crater is also shown by Compton and Petavius, whose transient cavity depths were approximately equal to the depth of the crust-mantle boundary in the regions in which they formed. Such a correlation of morphology with crustal thickness may lead to more comprehensive models of large crater and basin formation.

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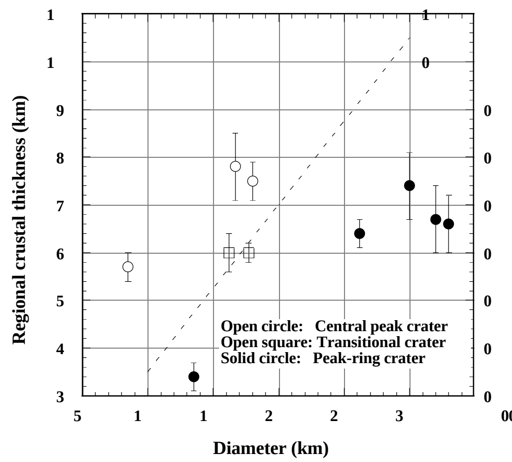

Figure 1. Crustal thickness vs. diameter for 3 central peak craters (Tycho, Hausen, and Tsiolkovsky), 5 peak-ring craters (Antoniadi, Milne, Schrodinger, Bailey, and Lorentz), and 2 transitional craters with both central peaks and peak-rings (Compton and Petavius). Dotted line is transient cavity depth assumed to be ~35% crater diameter.

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